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A Mixed Layer Model with Surface Wave Forcing

FINAL REPORT

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Background

This work was motivated by the desire to develop a mixed layer model which more successfully parameterized the principal physical processes responsible for mixing. The goal was improved prediction of the short–term (days to weeks) evolution of upper ocean vertical structure. Analysis of recent observations (Weller and Plueddemann, 1996; Gnanadesikan, et al., submitted) indicated that traditional mixed layer models performed poorly during periods immediately following strong wind events, when local winds were low but waves persisted. During these low–wind periods a one–dimensional mixed layer model predicted restratification in response to solar heating. However, observations showed that Langmuir cells persisted for up to one day after the end of the wind forcing (Plueddemann, 1996), redistributing the heat from the penetrating shortwave radiation, and keeping the surface layer mixed.

Since existing mixed layer models do not include surface waves as a part of the forcing, they cannot account for wave–current interaction, Langmuir circulation, or the subsequent effects on mixed layer development. We intended to incorporate these effects in a model by adding the surface wave Stokes drift to the forcing and parameterizing mixing due to Langmuir circulation. This objective was modified in the course of the project as described below.

Approach

Using data from the ONR Surface Waves Processes Program (SWAPP, (Plueddemann et al., 1996; Weller and Plueddemann, 1996), we developed and tested a preliminary mixing parameterization. Unfortunately, progress on the project slowed in late 1995 when the lead PI accepted a temporary assignment at the National Science Foundation as an Associate Program Manager. In April of 1996 it was recognized that the project could not be completed within the original time frame. It was decided that unused first year funds would be re–allocated. In a coordinated effort with the ONR Physical Oceanography Program, the first–year funds were used for instrumentation to supplement the Coastal Mixing and Optics (CMO) moored ar-

ray deployed by Lentz, Plueddemann and Anderson (ONR Grant N00014-95-1-0339). The objective of this effort was to improve the space-time resolution of the array so that CMO analyses could include a description of the vertical wavenumber–frequency spectrum of the internal wave field and its variability in response to surface forcing. The second–year funds were rescinded.

Results

Preliminary model runs incorporating surface waves stokes drift in the forcing and a parameterization of mixing due to Langmuir circulation were completed (Figures 1-3). Working with A. Gnanadesikan (at that time a WHOI Postdoc), a one-dimensional mixed layer model (Price, et al., 1986; henceforth PWP) was modified to include surface wave forcing. The mixing source term proportional to the wind stress in the PWP model was replaced with one proportional to wind stress times Stokes drift. The energy source was decreased with depth by exp(-H/L) where H is the mixed layer depth and L is the depth over which Langmuir circulation is strongly forced. The changes in stratification predicted from the revised model were not substantially different from the PWP model before or during storms. However, following two storms when Langmuir circulation persisted after decay of the wind, the revised model showed greatly reduced stratification, in better agreement with the observations. The performance of the extended model was encouraging, but a rigorous evaluation was not done and the model development must be considered incomplete.

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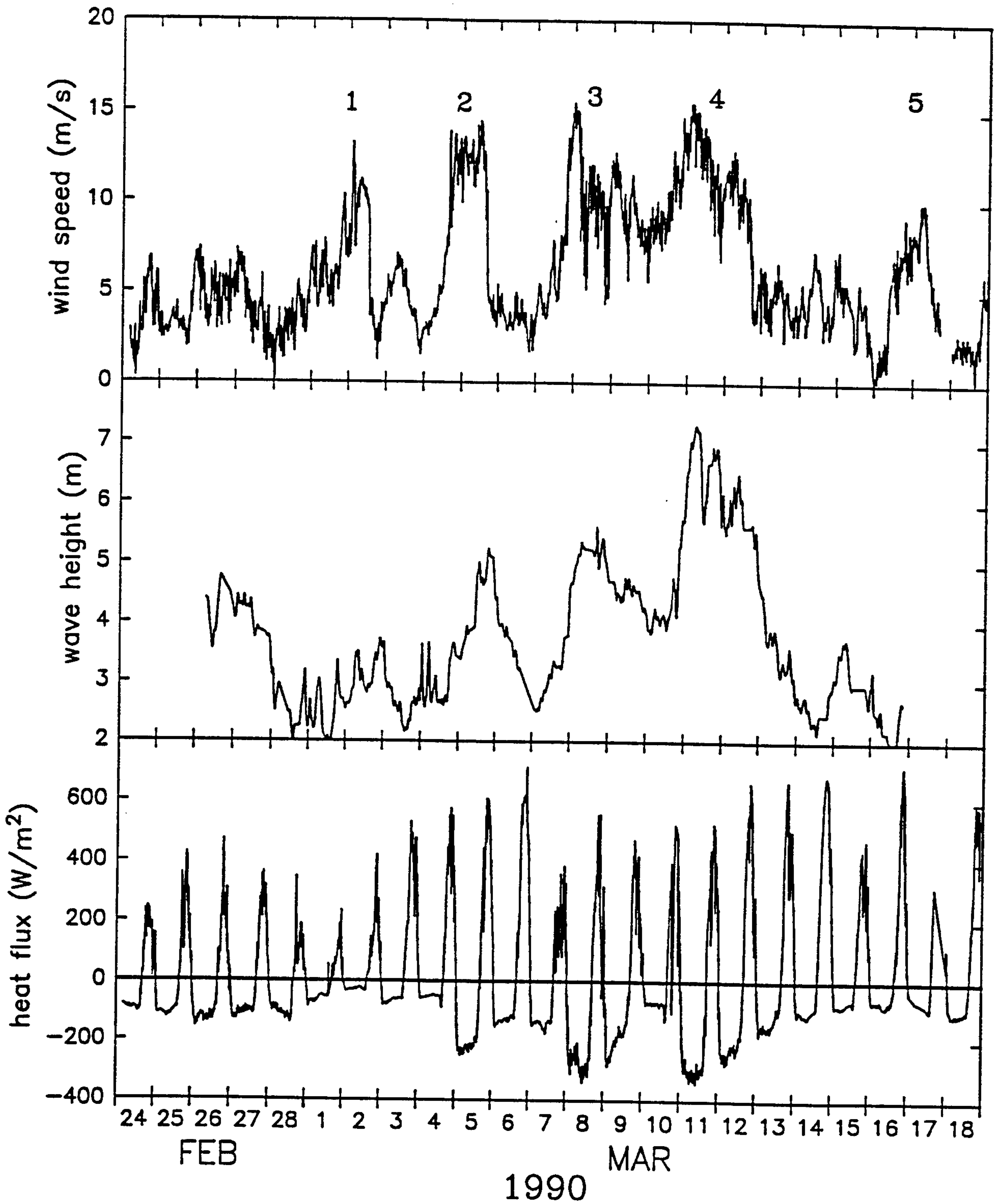

Figure 1: Time series of surface forcing during the Surface Waves Processes Program (SWAPP) Experiment. The wind speed (upper panel) was used to define five storm events. Growth in wave height (middle panel) is most apparent for events 2–4. The total heat flux (bottom panel) is dominated by diurnal heating.

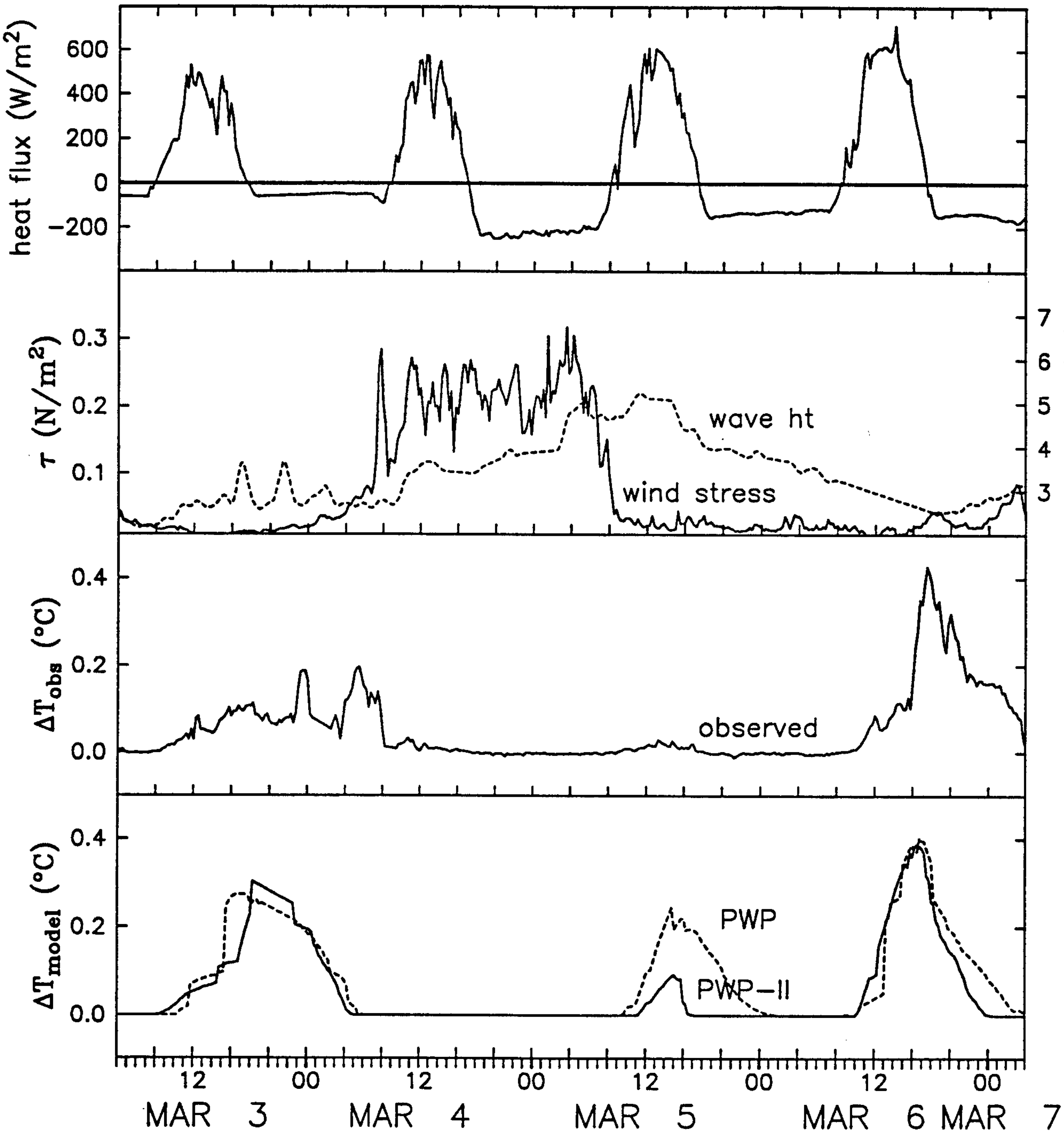

Figure 2: Comparison of observed and modelled near-surface stratification for Event 2. Forcing consists of heat flux (upper panel), wind stress and wave height (second panel). The observed 2 m–11 m temperature difference (third panel) shows no restratification on 5 March, even though the wind has decayed. Temperature difference from a model including surface wave forcing (PWP-II) is in better agreement with the data than the standard model (PWP).

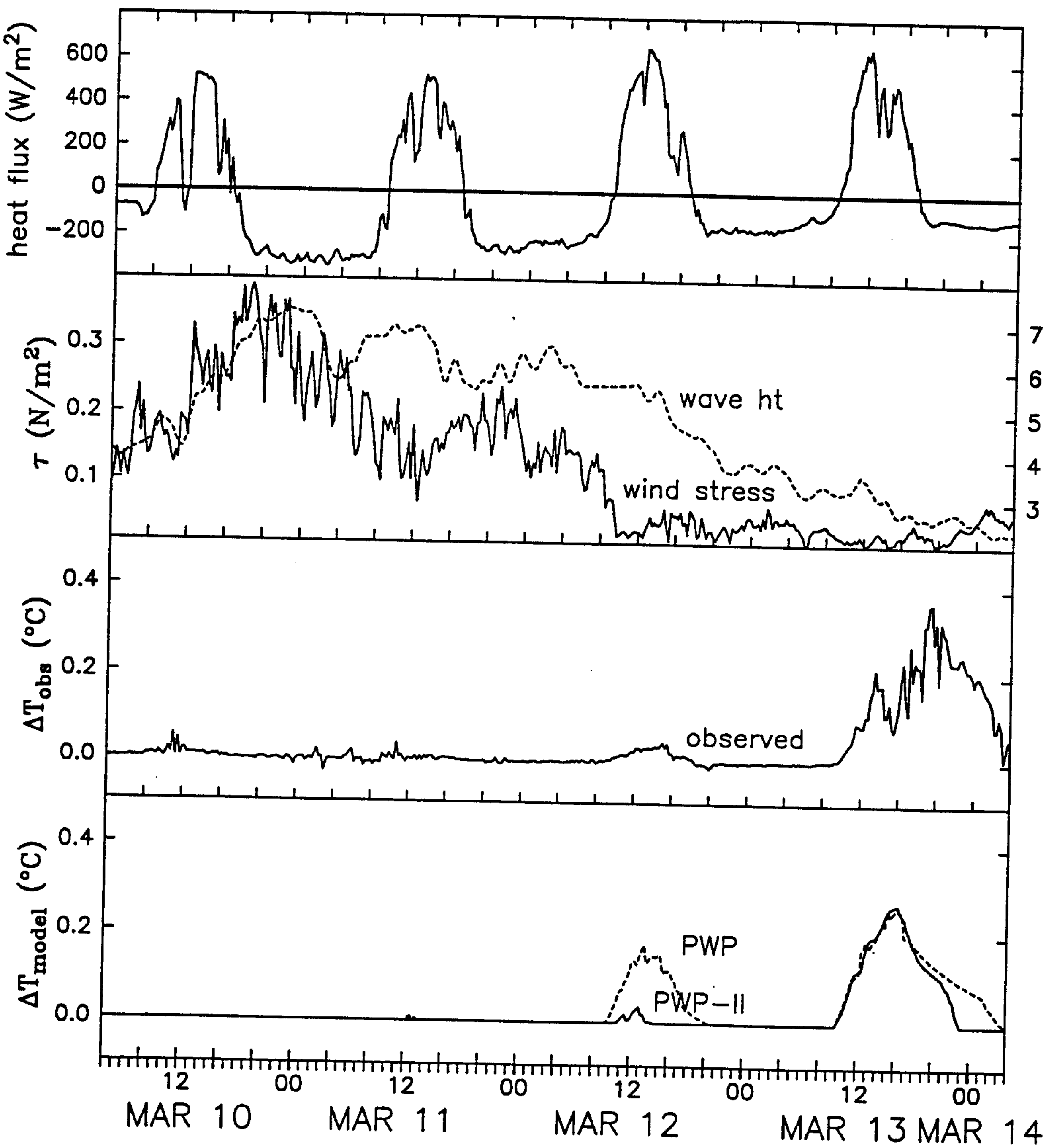

Figure 3: Comparison of observed and modelled near-surface stratification for Event 4. Forcing consists of heat flux (upper panel), wind stress and wave height (second panel). The observed 2 m–11 m temperature difference (third panel) shows no restratification on 12 March, even though the wind has decayed. Temperature difference from a model including surface wave forcing (PWP-II) is in better agreement with the data than the standard model (PWP).